

Laying a Foundation for Reusability of Knowledge Bases in Spacecraft Ground Systems

Mala Mehrotra

Pragati Synergetic Research Inc.
Yorktown, VA.

Sergio Alvarado

The Aerospace Corporation
Los Angeles, CA

Ross Wainwright

Air Force Research Lab
Kirtland AFB, NM

Ground Systems Architectures Workshop

March 3-5, 1999

**The Aerospace Corporation
El Segundo, CA**

Work performed at Pragati Inc. under AFRL SBIR contract

Outline

- MVP-CA Motivation
- MVP-CA Objective & Approach
- Characteristics of Satellite Systems
- MVP-CA's Relevance in Satellite Systems
- Telemetry Systems Analyzed to date
 - SEAES
 - XTE
 - UES
- MVP-CA Capabilities with focus on Reusability
- Related Work
- Conclusions

Work performed at Pragati Inc. under AFRL SBIR contract

Characteristics of Satellite Systems

- Spacecraft satellite telemetry (sub)systems have multiple configurable roles
- Similar rule bases in existence for different satellite subsystems
- Number of such rule bases with similar structure keeps growing as new missions get planned
- Number of rules in each such rule base keeps growing as knowledge evolves
- Complexity of a rule base depends on the:
 - number of rules, and
 - complexity of each pattern in the rule.

Motivation

Software Engineering of Large and Complex KBS is Difficult

- **Built by multiple teams**
 - ambiguities and interpretation problems
- **Knowledge evolves**
 - knowledge-base changes frequently
- **Scaling up problems for rapid prototyping systems**

Multi-ViewPoint Clustering Analysis (MVP-CA) Technology

Work performed at Pragati Inc. under AFRL SBIR contract

Objective

The objective of the MVP-CA technology is to facilitate

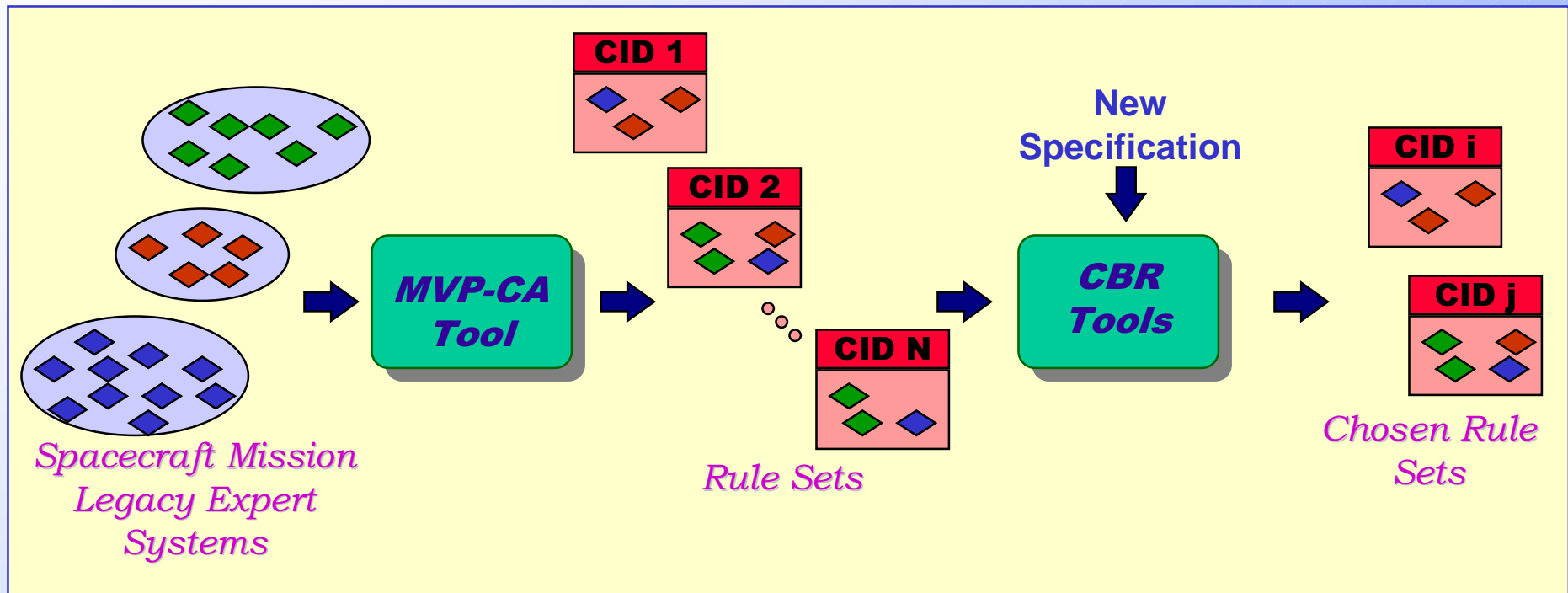
- Verification, Validation & Testing
- Reusability of Software Components across Missions
- Adaptability of Software Components across Missions
- Maintenance & Management of Large KBS

Approach

- Use agglomerative clustering algorithms to obtain semantically-related rule clusters
- “Similarity” defined by a set of heuristic distance metrics for determining distance between rules
- Zero-in on meaningful clusters with the aid of statistical and semantics-based cluster information

Work performed at Pragati Inc. under AFRL SBIR contract

MVP-CA Technology for Mission Rule Set Management



- Legacy expert systems can be clustered into **rule sets of semantically related rules**.
- **CBR tools** can then use the **Cluster Interface Definitions (CID)** of these rule sets for intelligent management, adaptation and assimilation of these rules across missions.

Work performed at Pragati Inc. under AFRL SBIR contract

Telemetry Systems Analyzed

- **Spacecraft Environmental Anomalies**
-- **SEAES** (Aerospace)
- **X-Ray Timing Explorer**
-- **XTE** (NASA Goddard)
- **Unexpected Events System Rule Base**
-- **UES** (ICS - part of the FUSE Project)

XTE

X-Ray Timing Explorer (NASA Goddard)

- *Problem Description*
 - Generic Spacecraft Analyst Assistant (GenSAA) - superset of Clips
 - Health & Safety Monitoring Rule base for various onboard subsystems
- *MVP-CA tool adapted for*
 - processing GenSAA rules
- *MVP-CA Tool discovered*
 - rule naming problems
 - reusable software components across the subsystems

Work performed at Pragati Inc. under AFRL SBIR contract

XTE Anomalies

Duplicate rule name:

Rule#	Rule Description
23	sa_status_check
27	xpndr_status_check
29	gsace_status_check
33	<i>tam_status_check</i>
35	<i>tam_status_check</i>
25	sds_status_check
31	rwa_status_check

Rule#	Rule Description
24	sa_limit_check
28	xpndr_limit_check
30	gsace_limit_check
34	tam_limit_check
36	pca_limit_check
26	sds_limit_check
32	rwa_limit_check

```
;Rule 35
(defrule tam_status_check ""
  (LimitStatus PAPCU1TMP2T#XTE_DECOM ?x1)
  ...
  ?o1 <- (Inferred PCA-Temp-Status ?cur_stat)
  (Inferred valid-telemetry valid)
=>
  ...
  (if (neq ?cur_stat ?new_stat) then
    ....
    then (SendMessage "MessageWindow" Status
      (str-cat "PCA Temperatures changed from " ?cur_stat " to " ?new_stat))
    else (SendMessage "MessageWindow" Warning
      (str-cat "PCA Temperatures changed from " ?cur_stat " to " ?new_stat))
    ...
  )
)
```

Work performed at Pragati Inc. under AFRL SBIR contract

Reusable Rule Sets

Objective:

To identify and store rule clusters which can be reused, possibly with adaptation, for new situations.

Issues:

- Identification of reusable component or rule clusters
- Specifying features which represents these clusters succinctly through Cluster Interface Definitions (CID)
- Retrieval of these clusters based on CIDs
- Adaptation of these clusters based on parameterizeable templates

Example Reusable Set: XTE

```
76 rcvr-1-lock2search
77 rcvr-1-search2lock
78 rcvr-2-lock2search
79 rcvr-2-search2lock
```

```
(defrule rcvr-1-lock2search ""
  (Mission XA1CARLK#XTE_DECOM
   ?r1&:(neq ?r1 LOCK))
  ?x1 <- (Inferred SC-Rcvr-1-Lock
         ?r3&:(neq ?r3 Search))
=>
  ...
  (SendMessage "MessageWindow" Status
   "Reciever 1 went from Locked to Search"))

(defrule rcvr-1-search2lock ""
  (Mission XA1CARLK#XTE_DECOM LOCK)
  (Mission XA1RCVLK#XTE_DECOM LOCK)
  ?x1 <- (Inferred SC-Rcvr-1-Lock Search)
  (Inferred valid-telemetry valid)
=>
  ...
  (SendMessage "MessageWindow" Status
   "Reciever 1 went from Search to Locked"))
```

```
(defrule rcvr-2-lock2search ""
  (Mission XA2CARLK#XTE_DECOM
   ?r1&:(neq ?r1 LOCK))
  ?x1 <- (Inferred SC-Rcvr-2-Lock
         ?r3&:(neq ?r3 Search))
=>
  ...
  (SendMessage "MessageWindow" Status
   "Reciever 2 went from Locked to Search"))

(defrule rcvr-2-search2lock ""
  (Mission XA2CARLK#XTE_DECOM LOCK)
  (Mission XA2RCVLK#XTE_DECOM LOCK)
  ?x1 <- (Inferred SC-Rcvr-2-Lock Search)
  (Inferred valid-telemetry valid)
=>
  ...
  (SendMessage "MessageWindow" Status
   "Reciever 2 went from Search to Locked"))
```

Work performed at Pragati Inc. under AFRL SBIR contract

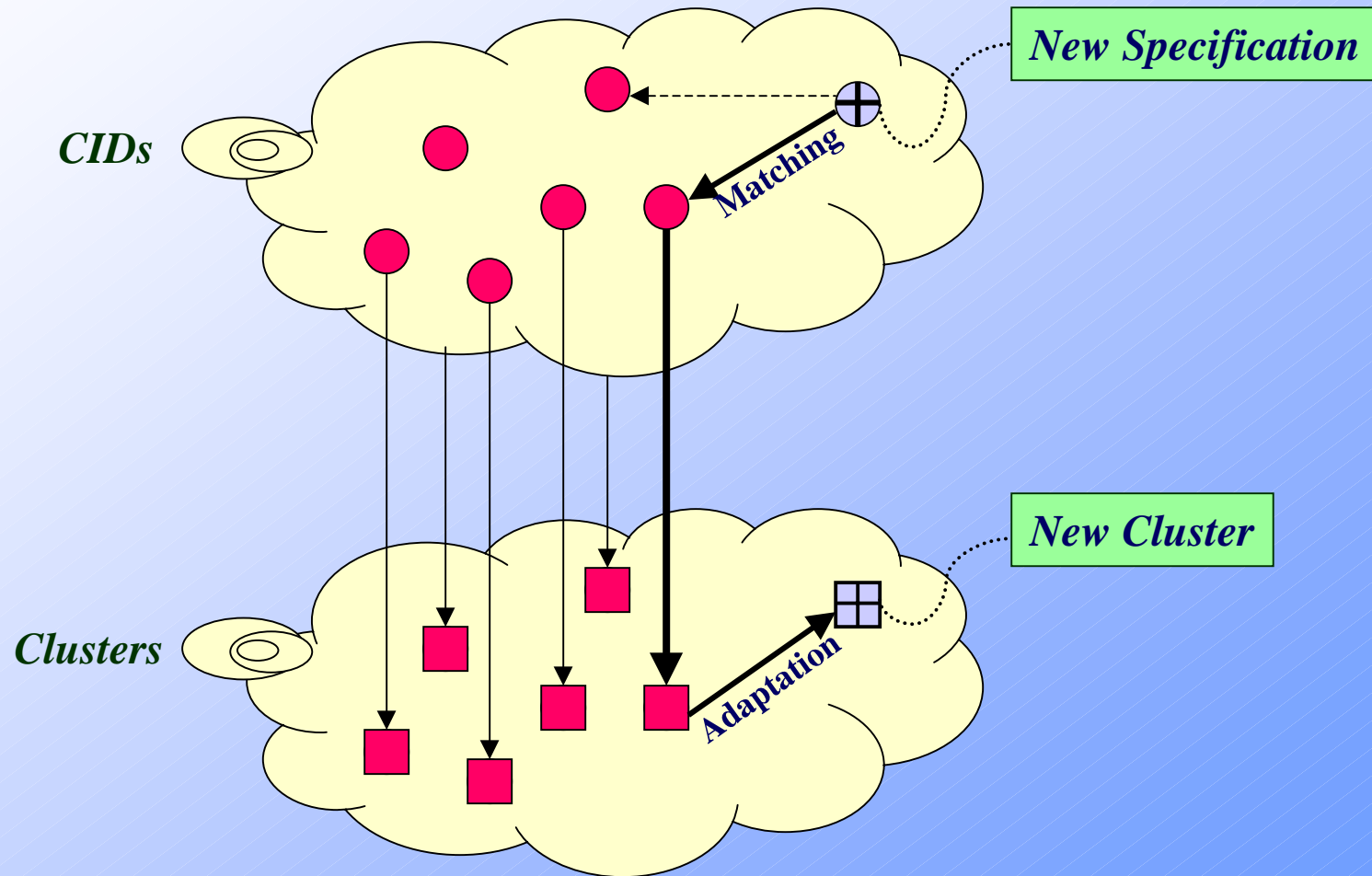
Example Reusable Set: XTE

```
2   tsm-0-22-watch
65  tsm-62-64-watch
12  tsm-24-watch
13  tsm-25-watch
39  tsm-68-watch
14  tsm-26-32-watch
17  tsm-65-66-watch
```

```
(defrule tsm-0-22-watch ""
  ?o1 <- (TSM-FAIL ?etime "ACS" ?id&:(and (>= ?id 0) (<= ?id 16)) ?thresh)
  ?o2 <- (acs-tsm-status ?)
  ?o3 <- (Inferred POWER-TSM-STATUS ?)
  ...
;*****
(defrule tsm-24-watch ""
  ?o1 <- (TSM-FAIL ?etime "SC" 24 ?thresh)
  ?o2 <- (Inferred POWER-TSM-STATUS ?)
  ...
;*****
(defrule tsm-25-watch ""
  ?o1 <- (TSM-FAIL ?etime "SC" 25 ?thresh)
  ?o2 <- (Inferred POWER-TSM-STATUS ?)
  ...
;*****
(defrule tsm-26-32-watch ""
  ?o1 <- (TSM-FAIL ?etime "SC" ?id&:(and (> ?id 25) (< ?id 33)) ?thresh)
  ?o2 <- (Inferred POWER-TSM-STATUS ?)
```

Work performed at Pragati Inc. under AFRL SBIR contract

Retrieval & Adaptation of Rule Sets: CBR Tools



Work performed at Pragati Inc. under AFRL SBIR contract

Representation of Rule Sets

- *Indexes* in CBR tools are used to represent & retrieve relevant cases.
- Indexes should be:
 - predictive - of the intended functionality of the cluster
 - abstract - to cover generality for incorporation of future cases in the case base
 - concrete - to be extracted efficiently for reuse
- Index repertoire should cover all dimensions of the domain.
- In this project, “cases” are software components, i.e., rule sets which perform a given function.
- Hence we require indexes which can capture all key aspects of the functionality of the rule sets.

Adaptation of Rule Sets

- Exact match of new scenarios will not be found always
- Thus rule sets will need to be adapted for reuse
- One mechanism is to store parameterized *templates* representing the rule set.
- Such templates would abstract the structure of the rule set and can be used for generation of new rule sets.

Sample Reusable Set

;CONTINUOUS BGM RULE DESCRIPTION: Trigger when MF_QUALITY is Good

(defrule **tlm_qual1**

(bgm-rule tlm_qual1 on)

(Mission MF_QUALITY#XTE_DECOM ~Nodata)

(Inferred fsync_lock_occurred yes)

=>

(AssertFact "Inferred Telem_Quality Good")

(SendMessage "MessageWindow" Status "MF_QUALITY indicates Telem quality is Good."))

;CONTINUOUS BGM RULE DESCRIPTION: Trigger when MF_QUALITY is Bad

(defrule **tlm_qual2**

(bgm-rule tlm_qual2 on)

(Mission MF_QUALITY#XTE_DECOM ~Good)

(Inferred fsync_lock_occurred ~yes)

=>

(AssertFact "Inferred Telem_Quality Bad")

(SendMessage "MessageWindow" Warning "MF_QUALITY indicates Telem quality is not Good.")

;CONTINUOUS BGM RULE DESCRIPTION: Trigger when MF_QUALITY drops out

(defrule **tlm_qual3**

(bgm-rule tlm_qual3 on)

(Mission MF_QUALITY#XTE_DECOM ~Good)

(Inferred fsync_lock_occurred ~yes)

(Inferred Telem_Quality Good)

=>

(AssertFact "Inferred Telem_Quality Bad")

(SendMessage "MessageWindow" Warning "MF_QUALITY indicates Telemetry has dropped out.")

Work performed at Pragati Inc. under AFRL SBIR contract

Possible Template for BGM Rules

```
defrule <name-of-rule>
  (bgm-rule <name-of-rule> on)
  (Mission MF_QUALITY#XTE_DECOM <data-quality-value>)
  (Inferred fsync_lock_occurred <f-l-value>)
=>
  (AssertFact "Inferred Telem_Quality <i-t-value>")
  (SendMessage "MessageWindow" <status-value>
    "MF_QUALITY indicates Telem quality is <t-value>.") )
```

Cluster-identification: *Input data-quality derives telemetry-quality*

Parameters:

Mission-name:	<i>MISSION</i>
Process-name:	<i>XTE-DECOM</i>
Input-data-source:	<i>MF-Quality</i>
Output:	<i>Telem-quality</i>
.....	

Work performed at Pragati Inc. under AFRL SBIR contract

Conclusions

- MVP-CA tool is applicable to
 - many types of telemetry expert systems, and
 - many expert system development platforms.
- It is scalable to large operational systems.
- Human-in-the-loop allows semantics of the KBS to be utilized in the clustering process.
- The tool aids in:
 - V & V - exposing anomalies and incompleteness
 - reusability.